Dynamic Emissivity Estimates to Support Physical Precipitation Retrievals for GPM

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1. Background

- Land surface emissivity is of critical importance for the microwave based precipitation retrieval algorithm development.
- Land surface emissivity is highly heterogeneous and dynamic. Therefore, it is difficult to estimate using physical model.
- We have developed a statistical framework to estimate land surface emissivity directly from brightness temperature (TBs).
- This method is successfully applied to Southern Great Plains (SGP) by Tian et. al. (2015), we now extend this framework to the GPM-covered region (65S-65N).
- We show two possible applications for this instantaneous emissivity estimation method in sections 5 and 6.

2. Data and Methodology

- Emissivity retrieved from GMI observed TBs via radiative transfer model (Joe Munchak)
- GMI TBs (V10, H10, V19, …, V89 and H89, total 9 channels) from 03/2014 to 12/2016, over land portion of 65S-65N.
- Emissivity from 10 to 89 GHz is regressed directly from TB-based predictors, including TB, TB[2], and Microwave Polarization Difference Index (MPDI, e.g., (V10-H10)/(V10+H10))
- We have tested five different regression models

  I. Method 1 (M1): single channel MPDI (10 GHz) and its square (2-predictor)

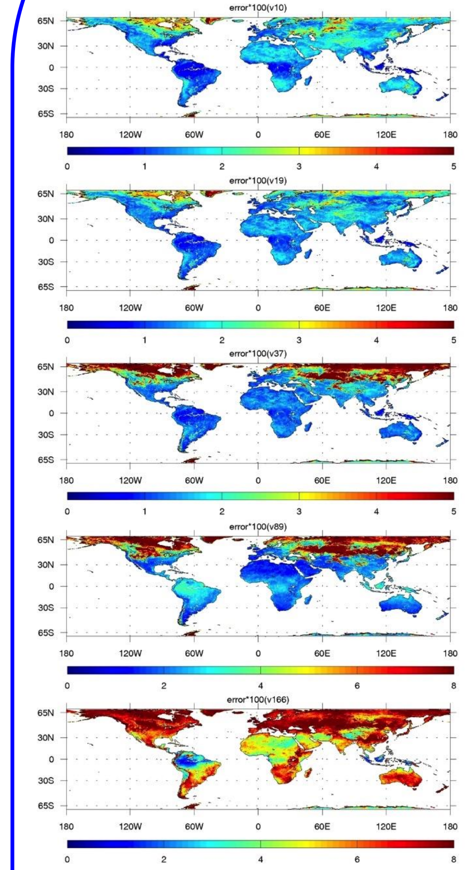
  II. Method 2 (M2): 4-channel MPDI (10, 19, 37, and 89G), linear terms only (4-predictor)

  III. Method 3 (M3): 9-channel TBs: 10~89 GHz, linear terms only (9-predictor)

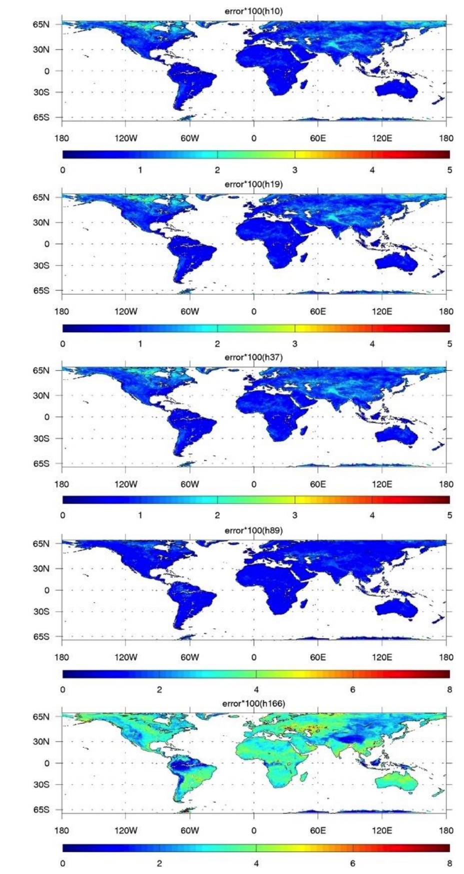
  IV. Method 4 (M4): 9-channel TB and 4-channel MPDI, linear terms only (13-predictor)

  V. Method 5 (M5): 9-channel TB, 9-channel TB[2], and 4-channel MPDI (22-predictor)

3. Emissivity Error Estimates



Emissivity error estimates from Method1 for 10 to 166 GHz. Only v-pol error estimates are shown. H-pol have similar geospatial pattern.



Emissivity error estimates from **Method5** for 10 to 166 GHz. Only v-pol error estimates are shown. H-pol have similar geospatial pattern.

- "Error" is defined as: the root-mean-square difference (RMSD), between the method's output and the radiative transfer model computed instantaneous emissivity data over the validation period (2016)

$$RMSD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(e_i - \hat{e}_i)^2}$$

- Compared with Method1, Method5 clearly has smaller error over the whole targeted region.
- Surface contamination (e.g., snow-covered land) likely plays an important role in the emissivity error estimation. Future work seeks to consider the surface type.

4. Error Table for M1 to M5 (%)

	M1	M2	M3	M4	M5
V10	1.85	1.53	1.43	1.38	1.33
H10	1.68	1.42	1.39	1.36	1.19
V19	1.81	1.48	1.44	1.39	1.39
H19	1.89	1.40	1.29	1.28	1.26
V24	1.99	1.62	1.55	1.51	1.47
V37	2.88	2.26	2.21	1.92	1.47
H37	3.15	2.16	2.01	1.90	1.36
V89	4.47	3.07	3.01	2.28	1.93
H89	4.82	3.02	3.06	2.38	2.03
V166	6.88	6.08	6.01	5.99	5.84
H166	7.33	7.17	7.01	6.92	6.62

- As expected, Method 1 performs worst for emissivity prediction, because it only relies on 10 GHz TB information.
- Method 5 has the best capability to estimate the emissivity for all channels from 10 to 166 GHz.
- Future work seeks to extend this analysis to all constellation radiometers.

We use Method 5 for two applications, with the purpose of improving the instantaneous precipitation retrieval results

(1) retrieve instantaneous rain rate by TB temporal variation at low freq. channels (e.g., 19 GHz) (see box 5). The idea is to use the surface emissivity temporal variation signal due to rainfall impact.

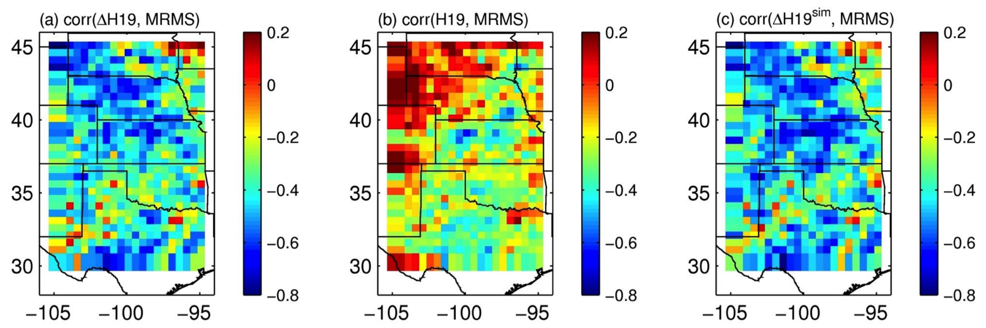
(2) re-index the category in the GPROF research database (see box 6). The idea is to use the instantaneous emissivity as the category index, instead of the index from the climatological emissivity database.

5. Application I: TB temporal variation at 19 GHz

- As a proof-of-concept, we use 19 GHz from 5 sensors, including GMI, SSMIS (F16, F17 and F18), and AMSR2, to derive **TB temporal variation (ΔTB).**
- **ΔTB may be defined as:** $\Delta TB = TB_{t_0} - TB_{t_{-1}}$. Where TB_{t_0} is the current TB associated with precipitation, and $TB_{t_{-1}}$ is the preceding TB at the same location without precipitation (see poster 232(a) for more details).
- **ΔTB can further be refined, using M5 to compute clear-sky emissivity:**

$$\Delta TB = TB_{t_0} - TB_{t_0}^{sim}$$

- where $TB_{t_0}^{sim}$ is the simulated TB using preceding clear-sky emissivity and current environmental parameters (e.g., temperature)

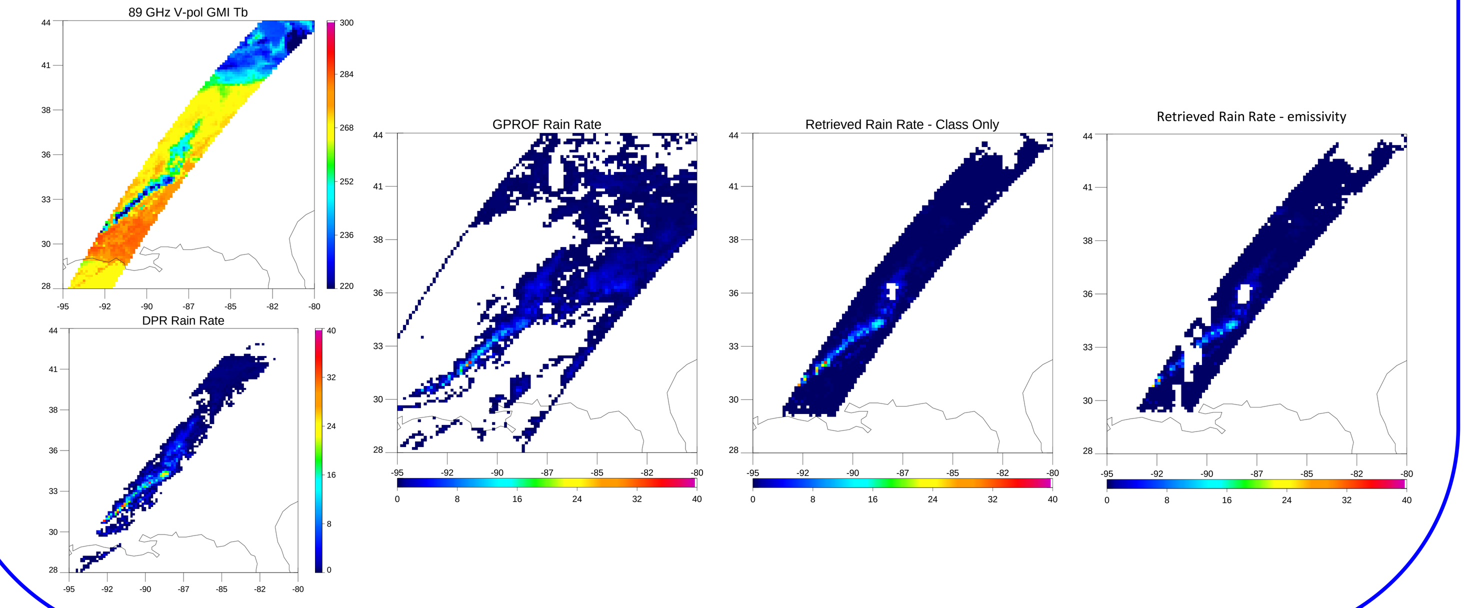


Correlation coefficients between MRMS precipitation rate over SGP and (a) ΔH19, (b) H19, and (c) $\Delta H19_{t_0}^{sim}$

Conclusion:ΔH19 correlates more strongly with rain rate, compare with H19 itself (cf. a and b). Using emissivity can further increase this correlation (cf. a and c).

6. Application II: Re-index the GPROF database

Preliminary testing in a Bayesian precipitation retrieval framework suggests several areas for future work. A case study was performed for a rain event in the southern US on February 1, 2001, using an orbit not included in the retrieval database. A "control" retrieval is performed using TPW, Tsfc, and TELSEM surface class as database indices, resulting in precipitation rates similar to those retrieved by the operational GPROF algorithm. A second retrieval is performed using the same database but now indexed using emissivity calculated using the method described here as the index in place of TELSEM class. As shown in the figures, rain rate patterns are retrieved successfully but are generally low. There is no retrieval in areas with inland water (Mississippi river) as the coefficients cannot be calculated there. The lower rain rates are a result of poor representation of high rain rates in the more stratified database. Future work will experiment with solutions such as a doubling of the database period for land pixels from one year to two, and moving from a Bayesian framework, which tends to smooth out higher rain rates, to other retrieval methods.



7. Conclusions

- A real-time land surface emissivity estimation method is extended to the GPM-covered region. The parameters in this method are directly derived from TBs without any ad hoc tuning, making it ideal for real-time application
- It is found that Method 5 has the best capability to predict the land surface emissivity, which captures the dynamic and heterogeneous emissivity characteristics over various regions, with average error of 1.33% to 6.62%
- We applied this technique to (1) retrieve instantaneous rain rate by TB temporal variation at low freq. channels (e.g., 19 GHz); and (2) re-index the category in the GPROF research database.

- **Tian, Y., et al., 2015, An examination of methods for estimating land surface microwave emissivity, *J. Geophys. Res. Atmos.,* 120, 11,114–11,128, doi:10.1002/2015JD023582.**
- **You, Y., C. Peters-Lidard, J. Turk, S. Ringerud, and S. Yang, 2017: Improving over land precipitation retrieval with brightness temperature temporal variation. *J. Hydrometeor.* doi:10.1175/JHM-D-17-0050.1.**
- **You, Y., C. Peters-Lidard, J. Turk, S. Ringerud, and S. Yang, N. Wang, R. Ferraro, 2017: Retrieving precipitation rate by brightness temperature temporal variation at 19 GHz over land. *J. Geophys. Res.* (submitted).**